17. (Amended) The apparatus as claimed in claim 16 wherein the drop off effects are also caused by an off-axis pixel projection effect.

21. (Amended) An apparatus for calibrating a camera comprising:

a retrieval routine which retrieves a digitized image of a blank textureless surface having a uniform illumination; and

a parameter computing routine which computes intrinsic parameters of the camera based on drop off effects in the digitized image caused by a vignetting effect.

22. (Amended) The apparatus as claimed in claim 21 wherein the drop off effects are also caused by an off-axis pixel projection effect.

REMARKS

Claims 1-25 are pending in the application. The Examiner has suggested that the Information Disclosure Statement filed on April 23, 1999 fails to comply with 37 CFR § 1.98(a)(2). The Examiner has objected to the drawings as failing to comply with 37 CFR § 1.84(p)(5). Claims 5, 10, 15, 20 and 25 have been rejected under 35 U.S.C. § 112 second paragraph, for insufficient antecedent basis. Claims 1-4, 6-9, 11-14, 16-19 and 21-24 are rejected under 35 U.S.C. § 103(b) as being unpatentable over U.S. 5,676,380 Patent No. 5,676,380 (Florent et al.) in view of U.S. Patent No. 5,084,772 (Shimoyama). In response, Claims 1, 6, 11, 16, 21 have been amended. Of the Claims, Claims 1, 6, 11, 16, and 21 are independent Claims.

Regarding Information Disclosure Statement

The Examiner has suggested that the Information Disclosure Statement filed on April 23, 1999 fails to comply with 37 CFR 1.98(a)(2) because the reference "Concepts of Classical Optics" pages 346-349 was not provided. The reference referred to by the Examiner as an abstract "Magnification, Aperture and Field" pages 346-349 is pages 346-249 of Chapter XV of the cited

reference "Concepts of Classical Optics". The table of contents of the cited reference "Concepts of Classical Optics" is submitted together with another copy of the referenced pages, to clarify that the reference cited in the IDS, filed on April 23, 1999, is "Concepts of Classical Optics" pages 346-349. The undersigned apologizes for the confusion in identifying the reference. Consideration of the cited reference is hereby requested.

The Examiner has suggested that copies of U.S. references listed on paper #2 (IDS) were not provided but have been considered. Form 1449 in the file of the undersigned does not cite any U.S. Patent Documents.

Regarding objections to the drawings

The Examiner has objected to the drawings as failing to comply with 37 CFR 1.84(p)(5) because they do not include reference signs mentioned in the description. In response, the specification has been amended to reference the reference signs shown in the drawings.

Regarding Rejections under 35 U.S.C. 112 second paragraph

Claims 5, 10, 15, 20 and 25 have been rejected under 35 U.S.C. § 112 second paragraph, for providing insufficient antecedent basis for the limitation "the model". The Applicants' claimed invention computes the parameters of a model by minimizing the difference between the digitized image and the model. (*See* Applicants' specification Page 5, lines 4-5, Page 12, lines 3-4 and lines 19-21, and Fig. 1, 118.) Each of the rejected Claims recites "a model" in line 2 and thus provides explicit antecedent basis for "the model" in line 3. (*See* MPEP 2173.05 (e).) Applicants respectfully request reconsideration of the rejection of Claims 5, 10, 15, 20 and 25 under 35 U.S.C. § 112 second paragraph.

Regarding Rejections under 35 U.S.C. 103(b)

Claims 1-4, 6-9, 11-14, 16-19 and 21-24 are rejected under 35 U.S.C. § 103(b) as being unpatentable over U.S. Patent No. 5,676,380 (Florent et al.) in view of U.S. Patent No. 5,084,772 (Shimoyama).

The Applicants claim a camera calibration technique that requires only a blank textureless surface, for example, a blank piece of paper, and uniform illumination. The camera optical and

physical shortcomings are used to extract the camera intrinsic parameters. The image of the blank textureless surface having uniform illumination is digitized. The intrinsic parameters of the camera are computed based on drop off effects in the digitized image. The drop off effects are caused by a vignetting effect. The parameters of a model are preferably computed by minimizing the difference between the digitized image and the model. One advantage of the Applicants' claimed calibration technique is that no special patterns are required. Thus, the Applicant's claimed technique recovers camera intrinsic parameters from a single image of a blank textureless surface.

In contrast to the Applicants' claimed method, the cited prior art, Florent, describes a technique for automatically calibrating a camera using a digitized image of a test pattern. The test pattern must have known exact dimensions, preferably a grating, with square shaped or rectangular shaped meshes in order to use the increase of the intensities at the intersections of the grating bars to extract reference points. The test pattern may be a series of dots, but use of the dot pattern is not as satisfactory as the grating. The use of a grating or test pattern is essential for the automatic calibration technique described by Florent. (See Col. 6, line 40; Col. 8, lines 4-8 and Col. 7, lines 55-61).

No special patterns are required for the Applicant's claimed camera calibration technique. Instead, the Applicants' claimed calibration technique uses "an image of a blank textureless surface having a uniform illumination". Florent's automatic calibration technique teaches away from the use of a blank textureless surface by requiring a test pattern. Therefore, the calibration technique described by Florent does not teach or suggest the Applicants' claimed method for computing the parameters of an imaging device "based on pixel intensity drop off effects" of a digitized "image of a blank textureless surface having a uniform illumination".

In contrast to the Applicants' claimed method for calibrating an imaging device by digitizing an image of a blank textureless surface having a uniform illumination, the cited prior art Shimoyama describes a technique for providing shading correction for photoelectric transduction elements in a line sensor in an image reading device. The image reading device includes a Charge Coupled Device (CCD) having an array of photoelectric transduction elements with each of the elements having different photoelectric conversion characteristics. Corrective data is generated for each element by irradiating a white paper having a uniform reflecting surface with light from a

light source. A document is scanned using a line sensor by moving the line sensor across the document using the same illumination used to generate the corrective data. After the document is scanned, a converted digital signal level of each photoelectric transduction element is corrected by the corresponding stored corrective data to obtain a reproduced image signal with shading correction. (See Col. 1, line 53- Col. 2, line 26.)

Shimoyama's technique for providing shading correction for an image produced by a line sensor does not teach or suggest the Applicants' claimed method for calibrating a camera based on pixel intensity drop off effects in the digitized image "caused by a vignetting effect" as claimed by the Applicants in Claim 1.

The characterization of the intensity of an image acquired using a line sensor is different to that acquired using a camera because an image acquired using a line sensor requires that the line sensor be moved relative to the image and thus the center projections differ between the images.

A vignetting effect results in the brightness of an image changing from the center of the image to the edge. A vignetting effect is not possible with an image created using a line sensor. Also, Shimoyama does not teach or suggest the effect of camera tilt on a digitized image because Shimoyama's line sensor scans the surface at the same place relative to the sensor.

Therefore, the Applicants' claimed invention is distinguished from Shimoyama because Shimoyama does not teach "computing intrinsic parameters . . . based on pixel intensity drop off effects . . . caused by a vignetting effect. Vignetting effects are not possible in Shimoyama's line sensor.

In combination, Florent and Shimoyama do not teach or suggest the Applicants' claimed invention for a method for calibrating an imaging device. The combination merely suggests that a camera can be automatically calibrated using a known test pattern and that shading correction can be provided for a line sensor through the use of stored correction data.

Dependent Claims 2-5, 7-10, 12-15 and 17-20 are also not obvious over the prior art because the combination does not describe or suggest the features of "computing the parameters of an imaging device based on pixel intensity drop off effects of a digitized image of a blank textureless surface having a uniform illumination" as with the present invention.

Dependent Claims 2-5, 7-10, 12-15 and 17-20 are patentably distinct and non-obvious over the cited art at least because they are based upon independent claims shown above to be

patentable, since the combination of the cited art does not contain any suggestion of "computing the parameters of an imaging device based on pixel intensity drop off effects of a digitized image of a textureless surface having a uniform illumination" as claimed by the applicants in amended Claim 1. Therefore, the Examiner's rejections of dependent Claims 2-14, 16-24 and 26-27 under 35 U.S.C. §103(a) as being deemed unpatentable over 5,676,380 Patent No. 5,676,380 (Florent et al.) in view of U.S. Patent No. 5,084,772 (Shimoyama) are improper and should be withdrawn.

CONCLUSION

In view of the above amendments and remarks, it is believed that all claims are in condition for allowance, and it is respectfully requested that the application be passed to issue. If the Examiner feels that a telephone conference would expedite prosecution of this case, the Examiner is invited to call the undersigned at (978) 341-0036.

Respectfully submitted,

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MARKED UP VERSION OF AMENDMENTS

Specification Amendments Under 37 C.F.R. § 1.121(b)(1)(iii)

Replace the paragraph at page 6, lines 16 through 18 with the below paragraph marked up by way of bracketing and underlining to show the changes relative to the previous version of the paragraph.

In FIG. 4B a source element dA is shown a distance away from the center of the source object [300] 400 below the optical axis 404. Light rays from the source element dA travel off-axis along an off-axis path [308] 408 at a field angle from the optical axis 404.

Claim Amendments Under 37 C.F.R. § 1.121(c)(1)(ii)

1. (Amended) A method for calibrating [an imaging device] a camera comprising the steps of:

digitizing an image of a blank textureless surface having a uniform illumination; and

computing [the effects] intrinsic parameters of the [imaging device] camera based on pixel intensity drop off effects in the digitized image caused by a vignetting effect.

2. (Amended) A method as claimed in Claim 1 wherein the pixel intensity drop off effect is also [dependent on] caused by an off-axis pixel projection effect.

6. (Amended) A computer program product for calibrating [an imaging device] a camera, the computer program product comprising a computer usable medium having computer readable code thereon, including program code which:

retrieves a digitized image of a blank textureless surface having a uniform illumination; and

computes intrinsic parameters of the [imaging device] camera based on drop off effects [of] in the digitized image caused by a vignetting effect.

7. (Amended) [A] The computer program product as claimed in claim 6 wherein the drop off effects are also [dependent on] caused by an off-axis pixel projection effect.

11. (Amended) A computer system comprising:

a memory system;

an I/O system connected to the memory system;

a storage device connected to the I/O system; and

a calibration routine located in the memory system responsive to a request for calibrating a camera [calibration] which:

retrieves a digitized image of a blank textureless surface having a uniform illumination; and

computes intrinsic parameters of the [imaging device] camera based on drop off effects [of] in the digitized image caused by a vignetting effect.

12. (Amended) [A] The computer system as claimed in claim 11 wherein the drop off effects are also [dependent on] caused by an off-axis pixel projection effect.

16. (Amended) An apparatus for calibrating [an imaging device] a camera comprising:

means for digitizing an image of a blank textureless surface having a uniform illumination; and

means for computing intrinsic parameters of the [imaging device] camera based on drop off effects in [of] the digitized image caused by a vignetting effect.

17. (Amended) [An] The apparatus as claimed in claim 16 wherein the drop off effects are also [dependent on] caused by an off-axis pixel projection effect.

21. (Amended) An apparatus for calibrating [an imaging device] a camera comprising:

a retrieval routine which retrieves a digitized image of a blank textureless surface having a uniform illumination; and

a paramcter computing routine which computes intrinsic parameters of the [imaging device] camera based on drop off effects in [of] the digitized image caused by a vignetting effect.

22. (Amended) [An] The apparatus as claimed in claim 21 wherein the drop off effects are also [dependent on] caused by an off-axis pixel projection effect.

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